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EP 0311505 A2 EP 0297589 A1 SU 000883781 A
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(54) Abstract Title
**Method for determining signal detection threshold in ESM communication system**


(57) The invention determines the signal detection threshold for a communications ESM (electronic support measures) signal detection system operating in non-white, unspecified noise. The method adapts to changes in the noise characteristics with time. The invention detects signals for a communications ESM system given a signal spectrum and detection threshold. It has the advantage that it does not require assumptions regarding channel frequencies. It utilises intelligent clustering of signal energy to avoid false alarms due to signal sideband energy. For thresholding, a modified spectrum M(f) is formed by adding a power of the frequency to the power spectrum. In thresholding, signal components are monitored for frequency difference and amplitude, to determine whether they are sidebands of each other (Fig 6 not shown).


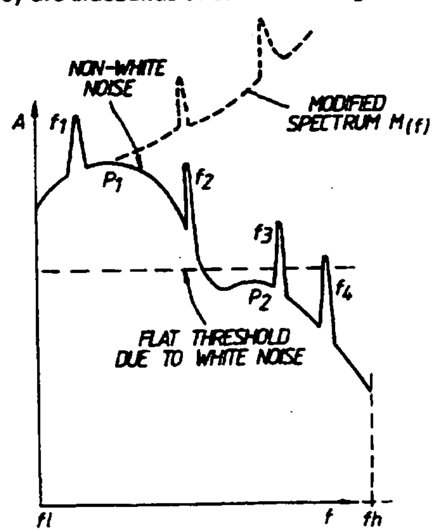


Fig.2.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977.

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# METHOD FOR DETERMINING SIGNAL DETECTION THRESHOLD IN ESM COMMUNICATION SYSTEM

The present invention relates to a method of determining a signal detection threshold in an ESM communications system.

ESM is an abbreviation for "electronic support measures", which measures are employed in electronic warfare systems. Electronic warfare systems commonly operate by scanning the frequency spectrum from HF to EHF ranges in order to detect all current communication signals, and then analysing the signals by means of computer techniques involving data bases etc., in order to determine which signals have been transmitted by an enemy. Appropriate counter measures may then be employed, such as jamming the communication channels of the enemy.

A common type of ESM system comprises a bank of passive antenna with associated receivers, each receiver responding to a desired frequency band of the overall frequency spectrum. A local oscillator signal within the receiver scans across the frequency band in recurrent cycles and the resultant IF signal is spectrally analysed. A suitable arrangement is shown in Figure 1 wherein an antenna 2 is connected to a receiver 4 having a local oscillator 5 which provides a wideband IF signal (say between 200 KHz and several MHz to a fourier transform unit 6. The IF signal is spectrally analysed in the fourier transform unit 6, which unit collates all the frequencies detected within the frequency band of interest together with their associated amplitudes. A spectrum of the IF signal is shown in Figure 2 as comprising peaks F1, F2, F3, F4 on a background noise which has

frequently due to interference from adjacent transmitting equipment and inherent characteristics of the receiving equipment.

Figure 2 shows a typical receiver for an ESM system as comprising an antenna 2, a receiver 4, and the output from the receiver 4 being a wide band IF signal, say 200KHz or several MHz. Normally receiver 4 is arranged to sweep across the entire frequency band so that the output IF signal sweeps across the band at a repetition rate determined by the receiver. The IF signal is analysed in a fourier transformer circuit 8 which identifies all frequencies within the wide band IF signal together with their amplitudes. The transformer 8 thus provides a spectrum of the IF signal and from this spectrum a threshold value is determined in circuit 10, so that any spectral energy having a value which is below the threshold is deemed not to be of interest. The threshold value is provided to a signal detection unit 12 which compare the threshold with the spectrum provided by the fourier transformer 8 and from this comparison determines signals which appear to be of interest.

It is an object of the present invention to provide a method of analysing received signals in a communications ESM system which accurately locates and identifies received signals and wherein the risk of false detection is reduced.

In general terms, the present invention provides a communications ESM system comprising;

an antenna and receiver responsive to a predetermined frequency band, the receiver including local oscillator means for producing a local oscillator signal which sweeps across the frequency

band in order to produce an IF signal which sweeps across the frequency band in recurrent cycles of operation;

fourier transform means for spectrally analysing the IF signal to determine the frequencies present in the IF signal for each sweep of the IF signal across the frequency bands;

means for determining a threshold value from the spectrally analysed IF signal so that for energy levels below the threshold, such energy values are not assumed to represent signals of interest;

signal detection means for comparing the spectrally analysed signals from the fourier transform means with the threshold value, said signal detection means including means for identifying peaks in the spectrum above said threshold value, and means for providing output signal descriptions to storage means of such signals.

In regard to noise threshold determination, it is not possible to make an assumption that for example the noise characteristics are constant with frequency, i.e. "white" noise, as shown from the dotted lines in Figure 1 which represents a white-noise such distribution, an entirely false set of signal values would be generated.

As regards prior systems for threshold determination, such systems have commonly assumed that the noise is in fact white noise with an energy level at any particular frequency determined according to the well-known Rayleigh probability distribution. In this case a noise level probability distribution is determined and employed to set a detection threshold, an assumption being made that a specified proportion of the peak signals detected will in fact be false detections. However, such a system cannot cope with non-white noise which severely alters the noise energy spectrum distribution.

It is possible to employ a "noise-whitening" filter, which provides a white noise distribution. However such a filter is of the adaptive type and requires an input having no communications signals therein in order to derive the correct filter coefficients; this cannot be guaranteed.

In order to overcome this specific problem, the present invention proposes a means of experimentally determining the noise distribution within a received frequency band of signals at frequent intervals and detecting peaks in the signal spectrum representing intelligent signals by comparing the signal with the experimentally determined threshold noise distribution.

The present invention therefore provides in a first specific aspect a communications ESM system, comprising;

a receiver arranged to receive signals within a predetermined frequency band, the receiver including local oscillator means arranged to sweep in frequency across the frequency band in order to provide an intermediate frequency (IF) signal at the output of the receiver which sweeps across the frequency band in recurrent cycles;

a fourier transform device for receiving said IF signal and for generating a frequency spectrum of the IF signal containing the relative signal amplitude of each frequency component within the frequency band;

means for determining a threshold value as a function of frequency and means for detecting signals within the frequency band by comparing the IF signal with the threshold value, the detection threshold means including:-

means for generating a pre-processed spectrum representing average values of the amplitude of the various signal components with the frequency band;

means for adding to said preprocessed spectrum a further signal whose amplitude varies in a predetermined manner according to a predetermined power of the frequency value thereby to derive a composite signal in which the overall envelope of the signal gradually increases as a function of frequency;

and means for determining from said modified spectrum an envelope which comprises a slowly varying signal which is less at all frequency points than the composite signal but which follows the trend of the composite signal, ignoring localised peaks and troughs; and wherein the signal detection means includes means for comparing the IF signal or signal spectra from said fourier transform unit with said derived threshold value in order to determine peaks of the IF signal.

Thus in accordance with the invention there is provided a method of experimentally determining a threshold value which varies as a function of frequency within the frequency band of interest and against which the detected signals may be compared to assess signal peaks within the detected signals. The experimentally determined threshold may be updated at frequent intervals in order to ensure that any sources of non-white noise which may be intermittent or rapidly varying will not significantly affect the identification of signal peaks.

The method of fitting an envelope to the lower contour of the signal from the frequency band window assessment is known as a

"convex hull" method and may be compared to stretching an elastic band around the lower contour of the received signal. In order to simplify the determination of the convex hull, a further term is added, preferably a quadratic term proportional to the square of the frequency value of interest which has the effect of removing unwanted peaks in the contour as will become apparent below. The convex hull is then determined and prior to comparing the determined threshold with the input frequencies signals, the further term is subtracted from the threshold value, preferably in a manner which is more specifically described below.

As regards the specific problem of determining which of the detected peaks are significant, one method of detection which has been used in the past to locate signals in the presence of noise is known as a peak picking method wherein each peak detected above a predetermined signal threshold is assumed to represent a separate signal. The problem with this technique is that side band signals tend to be classified incorrectly as separate signals and hence too many detected signals are identified.

Another method of signal detection is to divide the frequency band of interest into predetermined signal frequency "channels". If the energy within the channel is above a predetermined threshold barrier, then that channel is classified as containing a signal. The problem with this method is that signals may be spread across two or more adjacent channels, and hence erroneous signal detections are made. This may be due to signal centre frequencies not being aligned with the channel frequencies, resulting in energy being

spread over more than one channel, or may be due to a signal having a number of side bands which spread into adjacent channels.

The present invention provides in a second specific aspect a communications ESM system comprising;

an antenna and receiver responsive to a predetermined frequency band, the receiver including local oscillator means for producing a local oscillator signal which sweeps across the frequency band in order to produce an IF signal which sweeps across the frequency band in recurrent cycles of operation;

fourier transform means for spectrally analysing the IF signal to determine the frequencies present in the IF signal for each sweep of the IF signal across the frequency bands;

means for determining a threshold value from the spectrally analysed IF signal so that for energy levels below the threshold, such energy values are not assumed to represent signals of interest;

signal detection means for comparing the spectrally analysed signals from the fourier transform means with the threshold value, said signal detection means including;

means for identifying all peaks in each spectrum above said threshold value, means for measuring the difference in frequency between adjacent peaks and comparing adjacent peaks in terms of their relative amplitude and the frequency difference therebetween to determine whether one peak is a side band of the other; and,

providing output signal descriptions to storage means of those peak signals which are identified to be separate signals.

Thus in accordance with the invention means are provided for distinguishing between side band signals and actual signals in a

spectrum of received signals, which means does not suffer from the disadvantages of the method used previously. In particular it is not necessary to set predetermined frequency channels and analyse signals within each channel, it does not falsely identify side band signals as separate signals to be analysed. Further the method may be simply implemented requiring a minimum of processing and is suitable for use with high speed signal detection systems.

A preferred embodiment of the invention will now be described with reference to the accompanying drawings therein;

Figure 1 is a schematic view of the communications ESM system for use in the present invention;

Figure 2 is a typical schematic view of a received signal within the frequency band of interest;

Figure 3 is a schematic view of a "preprocessed" spectrum illustrating the method of determining the noise threshold in accordance with the invention;

Figure 4 is a block diagrammatic view of a means for determining the signal threshold in accordance with the invention; and,

Figure 5 is a schematic representation of a convex hull threshold value in relation to the preprocessed spectrum;

Figure 6 is a schematic view of a spectrum of an incoming signal which has been analysed so as to identify signal peaks above the threshold value; and,

Figure 7 is a block diagram of an embodiment of the signal detecting apparatus according to the present invention.

Referring now to the drawings, in Figure 1 the spectrally analysed signals from fourier transform unit 6 are fed to a detection threshold determination unit 8 whence a threshold is determined and compared with the spectrally analysed signals in signal detection unit 10 in order to determine peaks in the signal representing communications channels.

Figure 4 shows the determination unit 8 in more detail. As a first step spectra are averaged within a unit 12 over a short time scale to reduce fluctuations within the spectra. A predetermined number, as shown five, of consecutive averaged spectra are stored in a first in first out (FIFO) local store 14 which may for example comprise a shift register type store. A local window operator unit 16 is coupled to the store 14 and defines a window of predetermined frequency width which extends over all five stored spectra. This local window is scanned in frequency across the averaged stored spectra as is shown diagrammatically in Figure 3. At each frequency step during the scanning, the value of a "preprocessed spectrum" is computed as the maximum value of the power spectra within the local window. The effect of this procedure is to produce a pre-processed spectrum which has considerably less fluctuations and "troughs" than the original spectra.

The pre-processed spectrum is fed to a convex hull computing unit 18 which assesses the shape of the spectrum and fits a convex hull to the lower edge as indicated in Figure 5.

The convex hull is defined as the set of points on the pre-processed spectrum which define the lowest possible boundary. Figure 5 gives an example. (Consider the convex hull as the shape

resulting in stretching an elastic band across the lower edge of the pre-processed spectrum).

In order to facilitate 'concave' sections in the power spectrum, the convex hull is in fact fitted to a modified version of the pre-processed spectrum where the modified version consists of the original pre-processed spectrum with an additive quadratic frequency term, ie.:

$$M(f) = P(f) + a*f^2$$

where f represents frequency, M the modified power spectrum and P the pre-processed power spectrum. The constant 'a' determines the degree of concave curvature of the convex hull. Larger values of 'a' produce higher degrees of curvature.

The effect of the further term is indicated in Figure 2 where it may be seen the original curve which decreased for a maximum near the lower end of the frequency band, now rises from the lower end of the frequency band more or less continuously to the upper end of the frequency band. Thus the fitting of a convex hull to the base of the modified spectrum is a far simpler method. Convex hull determination is a well known process and is described for example in "A fast approximation to a convex hull" Z HUSSAIN Pattern Recognition Letters Vol. 8 No. 5 December 1988 pp 289-294 no further description being thought necessary since it would be apparent to a person skilled in the art.

Having determined the convex hull, various "anchor" points indicated as a $A_1 \ldots A_N$ are determined in the hull, and the value of the further term at these points is subtracted in order to determine the actual threshold level. Values of the convex hull are interpolated

between these anchor points and these interpolated values retain the further term in order to achieve a degree of concavity in the hull.

A detection margin is then added to the convex hull in order to produce the required detection threshold.

Note the use of the convex hull to determine a low boundary of the pre-processed spectrum. Spectral energy due to signals present in the spectrum is ignored by the action of convex hull and this energy is therefore excluded from determination of the noise floor and resulting detection threshold. The pre-processing scheme eliminates outliers in the data which would cause the low boundary to be set too low. Use of the additive quadratic term allows for concavity in the observed power spectra to be managed effectively.

Having determined the threshold in the above manner, the threshold is compared with the spectrally analysed IF signals in signal detection unit 10 in order to determine peaks F1, F2, F3, F4, which may represent communications channels or other signals of interest.

Referring now to Figures 6 and 7:

Figure 6 illustrates an example scenario; it shows a detection threshold and the spectral energy above threshold. Three signals are shown (i), (ii), (iii), one (signal (i)) having sidebands which temporarily fall below the detection threshold in regions a, b. It will be noted the spectral energy estimates have an equal frequency spacing, this being determined by the method of spectral analysis, involving fourier analysis of fixed width frequency channels. The letters v, w, A, B, C, D, P, Q refer to parts of the waveform at different processing stages in the system of figure 7.

Figure 7 provides an example circuit diagram to implement the method. The diagram shows only one side of the clustering circuitry for reasons of clarity. Two such circuits are generally required, or a modification to the circuit shown will enable it to perform the total function.

The hardware described by Figure 7 contains a number of maximum locators and edge locators which perform the following tasks:

(i) A max detector 20 locates the maximum value (and the ordinate of the maximum value) of the above detection threshold energy within the range specified by the upper and lower frequency limits. Detector 20 is coupled to edge detector 22, a select circuit 24, and edge detectors 26, 28.

(ii) An edge detector locates the position (ordinate) of the edges of the above detection threshold energy. The particular edge located (rising or falling) is determined by the control input (up or down). The starting position for searching for an edge is determined by the input signal to the detector (see Figure 4).

The above circuit functions may be implemented with counter and comparator logic devices.

Operation of the method (and apparatus) is now described with reference to Figure 6 and 7.

Given the "spectrum" of detected data and the upper and lower frequency limits of interest v, w (predefined parameters) (Figure 4), the location of largest signal peak (A) is identified by max detector 20.

The right side (highest frequency) edge of the above detection threshold data is located ((B) in Figure 3) by an edge detector 22 which starts searching from position (A) as shown in Figure 4. The selector 24 (Figure 4) is initially set to select the (B) input. The rising edge of the next energy segment (C) is located in detector 26.

The frequency difference (v) between the edge (B) and the rising edge of the next energy segment ((C) in Figure 3) is computed in a subtractor 30. The difference v is applied to a control unit 32.

If the frequency difference ((v) in Figure 3) is greater than a predefined threshold value stated in unit 32, then clustering halts and the frequency (B) is defined as the signal upper frequency of the band of signals comprising signal (i). This frequency is fed to the control unit 32 via the selector unit 24 for storage.

If the frequency difference (v) is below the predefined threshold, then the next segment is associated with the signal peak (A) if the following conditions are satisfied:

(i) A "window" of frequency width w is specified as shown in Figure 2 by applying a fixed signal w to a subtractor unit 34 where it is compared with the frequency signal from edge detector 26. The peak amplitude value (P) (Figure

2) within this window is located by a max detector 36 (Figure 4).

(ii) The peak amplitude value of the cluster under consideration (Q) (Figure 2) is located by a max detector (38) (Figure 4).

(iii) The values P and Q are compared in a ratio device 40, and if the value of Q/P does not exceed a predefined threshold, then the next cluster is associated with the signal peak, else the upper frequency (B) is defined as the signal upper frequency of signal (i) and a new signal begins thereafter.

This condition ensures that energy is clustered only if the peak power of the additional energy is in line with that expected, assuming the energy is a sideband of the signal under consideration. The ratio is determined by consideration of the spectrum of aims and from modulated signals in general terms.

If clustering has not halted due to the finding of an upper frequency limit, then clustering continues in a similar manner. The control function sets the selector 24 (Figure 4) to select the alternative input ((D) in this case) to selector 24, and the process continues by working upwards in frequency.

When clustering has halted due to the finding of an upper frequency limit, then the output of the selector function is the upper frequency limit for the signal. A similar process is followed for clustering on the low frequency side of the peak cluster (A) to provide the lower frequency limit of the signal.

When all clustering for peak (A) has halted, then the clustered data represent a single detected signal. Data from this signal is removed from the spectral data and the whole process ((a) to (g) above) is repeated until all above threshold energy has been allocated to a signal.

Figure 6 illustrates an example situation where three signals are detected. Signal (ii) is not clustered into signal (i) since the peak energy does not fall in line with the expected sideband power trend of signal (i) (See condition (e) above). Signal (iii) is not clustered into signal (ii) since the frequency difference (condition (d) above) between the edges of each signal exceeds the predetermined threshold.

CLAIMS

1. A communications ESM system comprising;

an antenna and receiver responsive to a predetermined frequency band, the receiver including local oscillator means for producing a local oscillator signal which sweeps across the frequency band in order to produce an IF signal which sweeps across the frequency band in recurrent cycles of operation;

fourier transform means for spectrally analysing the IF signal to determine the frequencies present in the IF signal for each sweep of the IF signal across the frequency bands;

means for determining a threshold value from the spectrally analysed IF signal so that for energy levels below the threshold, such energy values are not assumed to represent signals of interest;

signal detection means for comparing the spectrally analysed signals from the fourier transform means with the threshold value, said signal detection means including means for identifying peaks in the spectrum above said threshold value, and means for providing output signal descriptions to storage means of such signals.

2. A communications ESM system, comprising;

a passive antenna coupled to a receiver arranged to receive signals within a predetermined frequency band, the receiver including local oscillator means arranged to sweep in frequency across the frequency band in order to provide an intermediate frequency (IF) signal at the output of the receiver which sweeps across the frequency band in recurrent cycles;

a fourier transform device for receiving said IF signal and for generating a frequency spectrum of the IF signal containing the relative signal amplitude of each frequency component within the frequency band;

means for determining a threshold value as a function of frequency and means for detecting signals within the frequency band by comparing the IF signal with the threshold value, the detection threshold means including:-

means for generating a pre-processed spectrum representing average values of the amplitude of the various signal components with the frequency band;

means for adding to said preprocessed spectrum a further signal whose amplitude varies in a predetermined manner according to a predetermined power of the frequency value thereby to derive a composite signal in the overall envelope of the signal gradually increases as a function of frequency;

and means for determining from said modified spectrum an envelope which comprises a slowly varying signal which is less at all frequency points than the composite signal but which follows the trend of the composite signal, ignoring localised peaks and troughs.

3. A system as claimed in claim 2, wherein the generating means includes means for collating a predetermined number of spectra determined by said fourier transform unit in successive sweeps of the frequency band, means for defining a window occupying a predetermined frequency band within each of said plurality of spectra and means for determing the average amplitude or power of

the signal within the frequency band window, and means for sweeping the frequency band window across the spectra.

4. A system as claimed in claim 2, including means for averaging the frequency spectra over a relatively short interval prior to applying the spectra to a storage means within said collating means.

5. A system as claimed in any of claims 2 to 4 wherein the further term has a value which varies according to the square of the frequency.

6. A system as claimed in any of claims 2 to 5 including determining a set of anchor points in said envelope and substrating from said anchor points the value of said further term.

7. A communications ESM system comprising;

an antenna and receiver responsive to a predetermined frequency band, the receiver including local oscillator means for producing a local oscillator signal which sweeps across the frequency band in order to produce an IF signal which sweeps across the frequency band in recurrent cycles of operation;

fourier transform means for spectrally analysing the IF signal to determine the frequencies present in the IF signal for each sweep of the IF signal across the frequency bands;

means for determining a threshold value from the spectrally analysed IF signal so that for energy levels below the threshold, such energy values are not assumed to represent signals of interest;

signal detection means for comparing the spectrally analysed signals from the fourier transform means with the threshold value, said signal detection means including;

means for identifying all peaks in each spectrum above said threshold value, means for measuring the difference in frequency between adjacent peaks and comparing adjacent peaks in terms of their relative amplitude and the frequency difference therebetween to determine whether one peak is a side band of the other; and, providing output signal descriptions to storage means of those peak signals which are identified to be separate signals.

8. A system as claimed in claim 7, wherein in said comparison of adjacent peaks, the largest peak in the spectrum is located, and the adjacent peaks are compared with the largest peak, until a region is located in which no peak exists, this region being taken as bounding the edge of a side band.

9. A system as claimed in claim 8 wherein having determined the edge of a side band, the peak next adjacent the sideband is compared in frequency with the edge of the sideband, and if the difference is greater than a predetermined threshold value, the side band edge is confirmed as such.

10. A system as claimed in claim 9 wherein the difference is less than said predetermined threshold value, a window is defined of a fixed frequency width extending from said next adjacent peak, and

the peak within said side band and within said window having the largest value is determined.

11. A system as claimed in claim 10 wherein signals adjacent to said next adjacent peak are analysed and if adjudged to form a further sideband, the largest peak within the further side band is determined, and compared in amplitude with said largest value peak and wherein if the ratio of amplitudes does not exceed a predetermined threshold, then the further side band is determined to form part of the first mentioned side band.

12. Communications ESM systems substantially as described with reference to the accompanying drawings.

Amendments to the claims have been filed as follows

1. A communications ESM system comprising;

an antenna coupled to a receiver, the receiver being responsive to a predetermined frequency band, the receiver including local oscillator means for producing a local oscillator signal which sweeps across a first frequency band in order to produce an IF signal which sweeps across a second frequency band in recurrent cycles of operation;

fourier transform means for spectrally analysing the IF signal to determine the frequencies present in the IF signal for each sweep of the IF signal across the second frequency band;

means for determining a threshold value from the spectrally analysed IF signal so that for energy levels below the threshold, such energy values are not assumed to represent signals of interest;

signal detection means for comparing the spectrally analysed signals from the fourier transform means with the threshold value, said signal detection means including means for identifying peaks in the spectrum above said threshold value, and means for providing output signals indicative of the comparison.

2. A communications ESM system, comprising:

a passive antenna coupled to a receiver, the receiver being arranged to receive signals within a predetermined frequency band, the receiver including local oscillator means arranged to sweep in frequency across a first frequency band in order to

provide an intermediate frequency (IF) signal at the output of the receiver which sweeps across a second frequency band in recurrent cycles;

a fourier transform means for receiving said IF signal and for generating a frequency spectrum of the IF signal containing the relative signal amplitude of each frequency component within the second frequency band;

detection threshold means for determining a threshold value as a function of frequency and means for detecting signals within the second frequency band by comparing the frequency spectrum of the IF signals with the threshold value;

the detection threshold means including:

means for generating a pre-processed spectrum representing average values of the amplitude of the various signal components within the second frequency band;

means for adding to said pre-processed spectrum a further signal whose amplitude varies in a predetermined manner according to a predetermined power of the frequency value thereby to derive a composite signal, and means for determining from said composite signal a convex hull which comprises a varying signal which is less at all frequency points than the composite signal but which follows in frequency the composite signal, ignoring localised peaks and troughs.

3. A system as claimed in claim 2, wherein the generating means includes means for collating a predetermined number of spectra determined by said fourier transform means in successive sweeps of the second frequency band, means for

defining a window occupying a predetermined frequency band within each of said plurality of spectra and means for determining the average amplitude or power of the signal within the frequency band window, and means for sweeping the frequency band window across the spectra.

4. A system as claimed in claim 2, including means for averaging the frequency spectra over a relatively short interval prior to applying the spectra to a storage means within said collating means.

5. A system as claimed in any of claims 2 to 4, wherein the further signal has a value which varies according to the square of the frequency.

6. A system as claimed in any of claims 2 to 5, including determining a set of anchor points in said convex hull and substracting from said anchor points the value of said further signal.

7. A ESM communications system comprising;

an antenna coupled to a receiver, the receiver being responsive to a predetermined frequency band, the receiver including local oscillator means for producing a local oscillator signal which sweeps across a first frequency band in order to produce an IF signal which sweeps across a second frequency band in recurrent cycles of operation;

fourier transform means for spectrally analysing the IF signal to determine the frequencies present in the IF signal for each sweep of the IF signal across the second frequency band;

means for determining a threshold value from the spectrally analysed IF signal so that for energy levels below the threshold, such energy values are not assumed to represent signals of interest;

signal detection means for comparing the spectrally analysed signals from the fourier transform means with the threshold value, said signal detection means including;

means for identifying all peaks in the spectrally analysed signals from the fourier transform means above said threshold value, means for measuring the difference in frequency between adjacent peaks and comparing adjacent peaks in terms of their relative amplitude and the frequency difference there between to determine whether one peak is a side band of the other; and,

providing output signals indicative of those peak signals which are identified to be separate signals.

8. A system as claimed in claim 7, wherein in said comparison of adjacent peaks, the largest peak in the spectrum is located, and the adjacent peaks are compared with the largest peak, until a region is located in which no peak exists, this region being taken as bounding the edge of a sideband.

9. A system as claimed in claim 8, wherein having determined the edge of a sideband, the peak next adjacent the sideband is compared in frequency with the edge of the sideband, and if the

difference is greater than a predetermined threshold value, the sideband edge is confirmed as such.

10. A system as claimed in claim 9, wherein the difference is less than said predetermined threshold value, a window is defined of a fixed frequency width extending from said next adjacent peak, and the peak within said sideband and within said window having .the largest value is determined.

11. A system as claimed in claim 10, wherein signals adjacent to said next adjacent peak are analysed and if adjudged to form a further sideband, the largest peak within the further sideband is determined, and compared in amplitude with said largest value peak and wherein if the ratio of amplitudes does not exceed a predetermined threshold, then the further sideband is determined to form part of the first mentioned sideband.

12. Communications ESM systems substantially as described with reference to the accompanying drawings.

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**Patents Act 1977**
**Examiner's report to the Comptroller under Section 17 (The Search Report)**

Application number

9008393

**Relevant Technical fields**

(i) UK Cl (Edition K ) G1U: U2316, U23173; H4L: LFM

(ii) Int Cl (Edition 5 ) G01R

**Databases (see over)**

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI, CLAIMS, INSPEC

Search Examiner

G A McLEAN

Date of Search

8 OCTOBER 1990

Documents considered relevant following a search in respect of claims 1 - 12

| Category (see over) | Identity of document and relevant passages | Relevant to claim(s) |
|---|---|---|
| X, P | EP 0,311,505 A2(THOMSON) - especially lines 29 - 35, page 2; lines 6 - 64, page 6; Figures 9 and 10 | 1 |
| X, Y | EP 0,297,589 A1(ANRITSU) - especially line 11 - 27, column 1; lines 25 - 45, column 3; claim 7 | 1, 7 |
| X, Y | SU 883,781(BLATOV) - especially abstract; Figure | 1, 7 |
| A | Pattern Recognition Letters, Vol. 8, No. 5, December 1988, pages 289 - 295.<br><br>Article by Z Hussain, as acknowledged in the application. | |

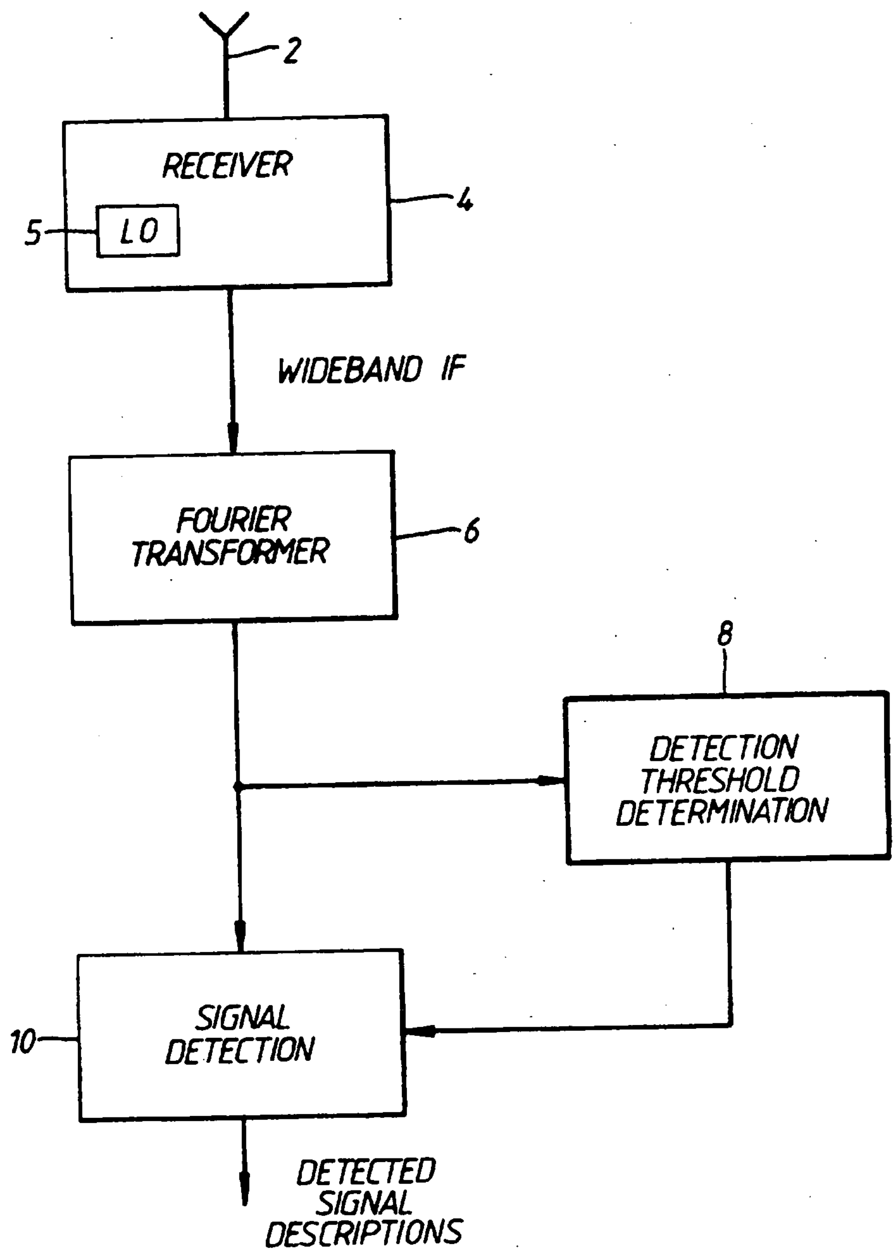

2
RECEIVER
4
5
LO
WIDEBAND IF
FOURIER TRANSFORMER
6
8
DETECTION THRESHOLD DETERMINATION
SIGNAL DETECTION
10
DETECTED SIGNAL DESCRIPTIONS

Fig. 1.

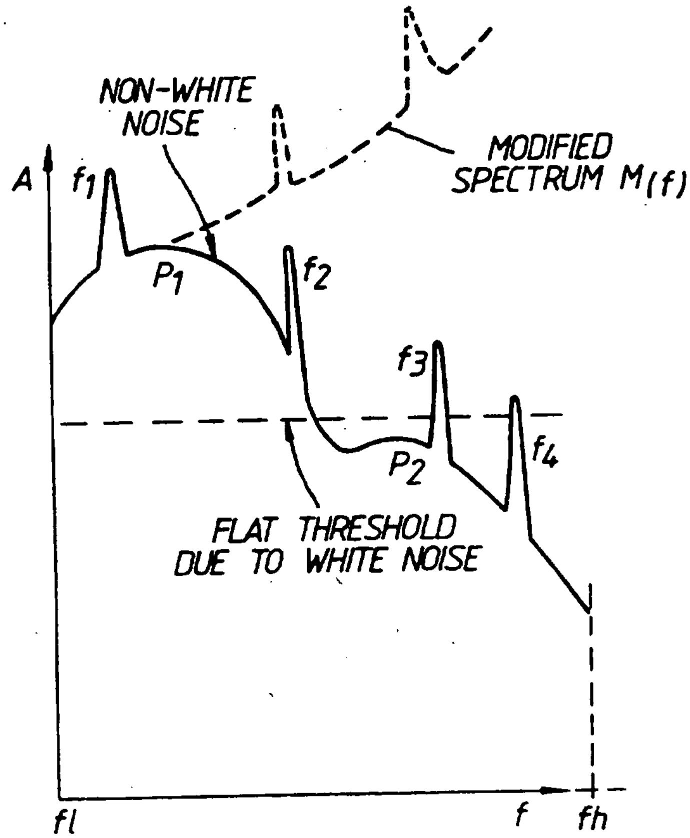

NON-WHITE NOISE
MODIFIED SPECTRUM M(f)
A
f1
P1
f2
f3
f4
P2
FLAT THRESHOLD DUE TO WHITE NOISE
fl
f
fh

Fig. 2.

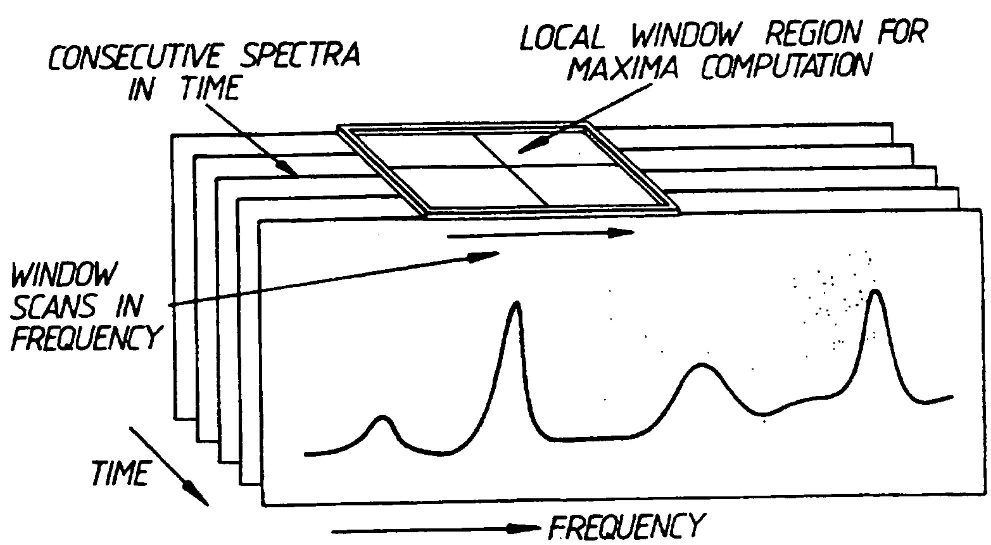

CONSECUTIVE SPECTRA IN TIME
LOCAL WINDOW REGION FOR MAXIMA COMPUTATION
WINDOW SCANS IN FREQUENCY
TIME
FREQUENCY

Fig. 3.

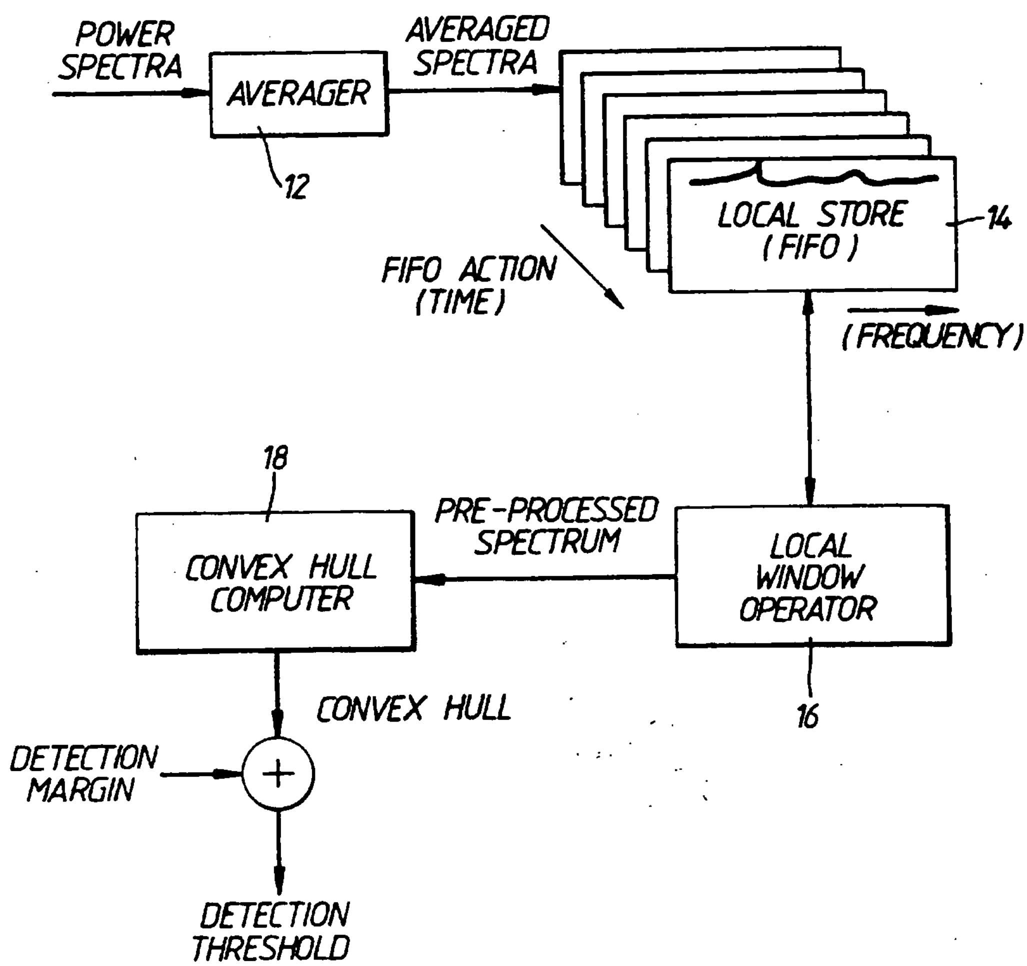

POWER SPECTRA
AVERAGER
12
AVERAGED SPECTRA
LOCAL STORE (FIFO)
14
FIFO ACTION (TIME)
(FREQUENCY)
18
PRE-PROCESSED SPECTRUM
CONVEX HULL COMPUTER
LOCAL WINDOW OPERATOR
16
CONVEX HULL
DETECTION MARGIN
+
DETECTION THRESHOLD

Fig.4.

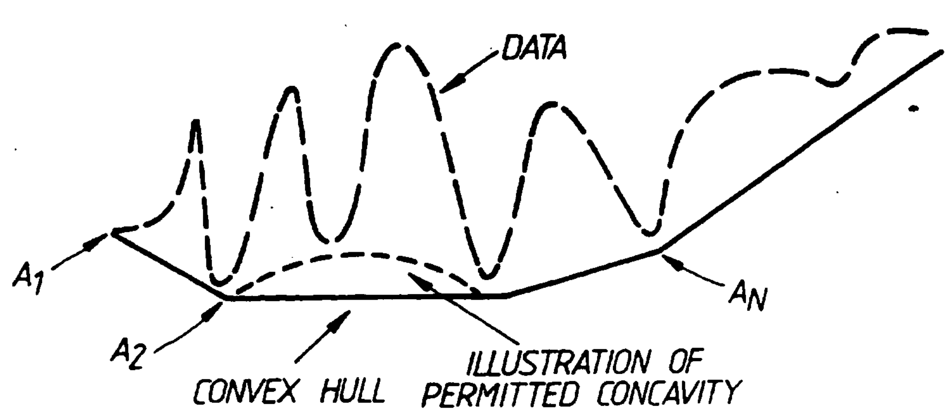
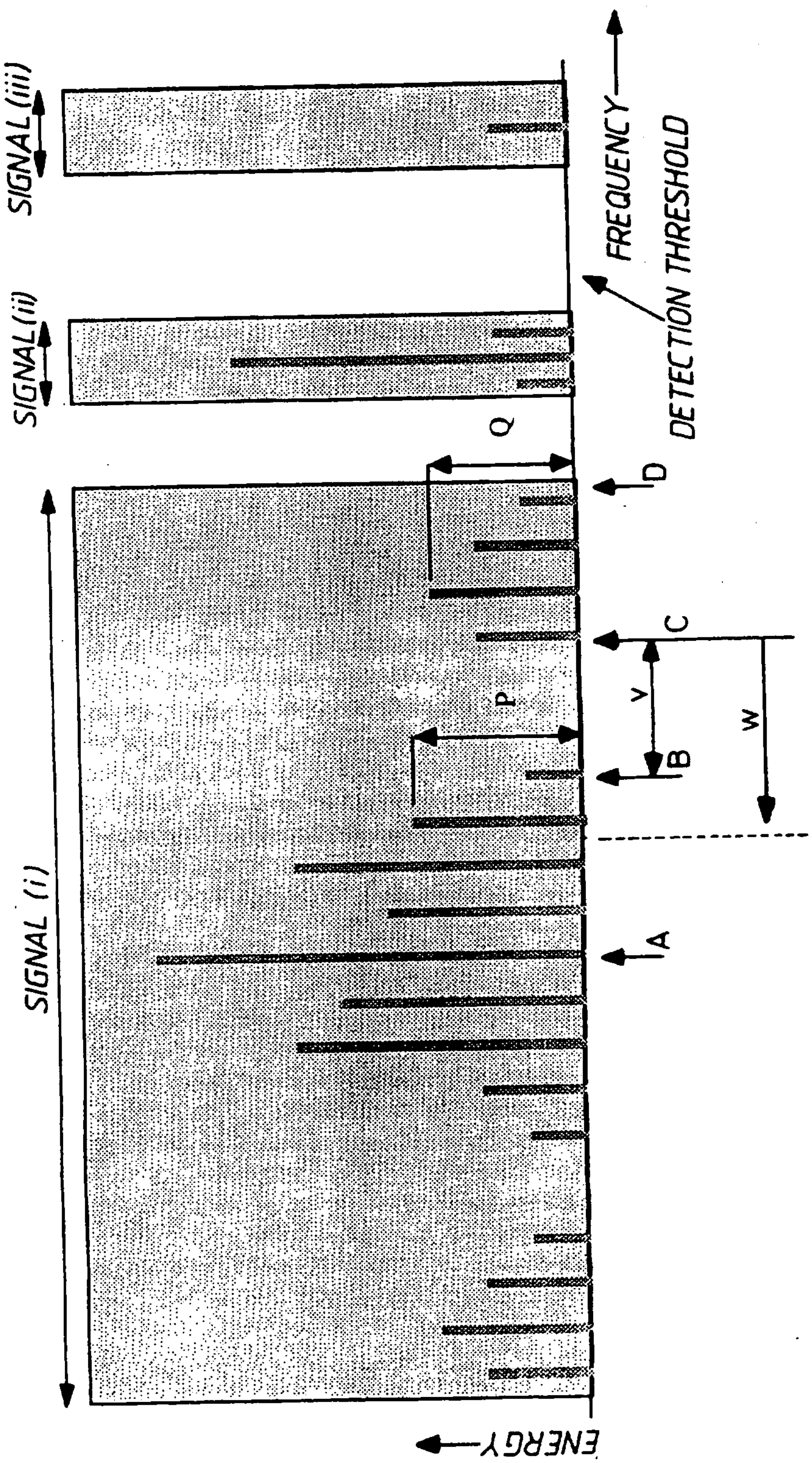
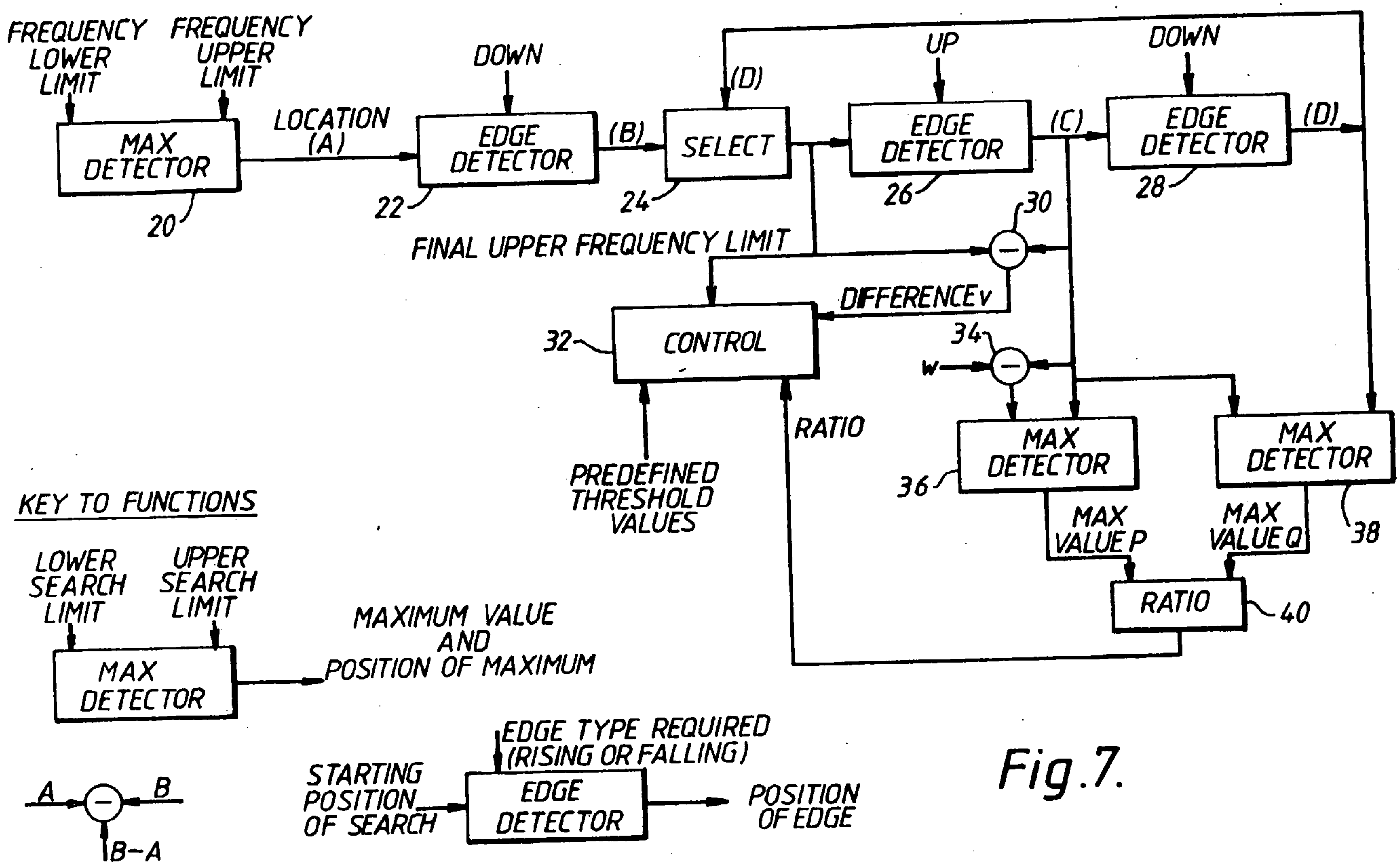

DATA
$A_1$
$A_2$
$A_N$
CONVEX HULL
ILLUSTRATION OF PERMITTED CONCAVITY

Fig.5.



SIGNAL (iii)
SIGNAL (ii)
SIGNAL (i)
FREQUENCY
DETECTION THRESHOLD
ENERGY
Q
P
D
C
B
A
V
W


Fig. 6.



FREQUENCY LOWER LIMIT
FREQUENCY UPPER LIMIT
MAX DETECTOR
20
LOCATION (A)
DOWN
EDGE DETECTOR
22
(B)
SELECT
24
(D)
UP
EDGE DETECTOR
26
(C)
DOWN
EDGE DETECTOR
28
(D)
30
FINAL UPPER FREQUENCY LIMIT
DIFFERENCE v
CONTROL
32
34
w
PREDEFINED THRESHOLD VALUES
RATIO
MAX DETECTOR
36
MAX DETECTOR
38
MAX VALUE P
MAX VALUE Q
RATIO
40
KEY TO FUNCTIONS
LOWER SEARCH LIMIT
UPPER SEARCH LIMIT
MAX DETECTOR
MAXIMUM VALUE AND POSITION OF MAXIMUM
A
B
B−A
EDGE TYPE REQUIRED (RISING OR FALLING)
STARTING POSITION OF SEARCH
EDGE DETECTOR
POSITION OF EDGE


Fig.7.